REMARKS

Claims 1-31 remain in the application as originally submitted.

The specification is amended to correct a typographical error noted by the Examiner. No other errors were discovered in the specification during the undersigned's review in preparation of this Response. The Examiner's attention to such detail is appreciated.

Claims 1-31 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Watanabe et al. Applicant disagrees and requests reconsideration.

The Examiner is reminded that the application must be reviewed in accordance with 35 U.S.C. §112 as Applicant "regards" its invention. How an Applicant regards its invention is in the manner which Applicant claims the invention. Accordingly, the Examiner needs to consider the obviousness inquiry in the context of Applicant's specific claims, and not in any manner which the Examiner might regard the Applicant's invention apart from the literal claims.

The Examiner asserts that Watanabe et al. discloses a capacitor having a high k capacitor region with three layers of metal oxides of varying stoichiometric potential, and that as such, Watanabe et al. describes various elements and combinations of elements that could be used to arrive at Applicant's various claims. Yet, each of Applicant's claims inherently recites separately what Applicant regards as its invention. And, Applicant's instant

claims are in no way of a breadth which covers <u>all</u> high k metal oxide regions only having some varying stoichiometric potential therein. Rather, each of Applicant's claims are expressly directed to specific attributes which are neither shown nor suggested by Watanabe et al., as further pointed out below.

The Examiner is also reminded that when applying 35 U.S.C. §103, the claimed invention must be considered <u>as a whole</u>, and any applied reference must likewise be considered as a whole. MPEP §2141. Further, in determining the differences between the prior art and the claims, the question under 35 U.S.C. §103 is not whether differences <u>themselves</u> would have been obvious, but whether the claimed invention <u>as a whole</u> would have been obvious. MPEP §2141.02. In addition, a prior art reference must be considered in its entirety, i.e., <u>as a whole</u>, including portions that would lead away from the claimed invention. MPEP §2141.02. Also, there must be some suggestion or motivation to modify a reference to arrive at the Applicant's claim, and none is seen in Watanabe et al. MPEP §2143.01.

More specifically, Applicant's independent claim 1 combination includes a high k capacitor dielectric region of metal oxide having multiple different metals bonded with oxygen and having varying stoichiometry across its thickness. Yet, further included in the claim 1 combination is recitation that the layer comprise an inner region, a middle region and an outer region, where the middle region has <u>a different stoichiometry than both the inner and outer regions</u>. This is neither shown nor suggested by Watanabe et al.

While Watanabe et al. might be considered as disclosing inner, middle and outer regions, each of its examples specifically referring to the same provide the middle region to have the same stoichiometry as at least one of the inner and outer regions. (IEC Table 1, and the language pertaining thereto). The other reference in Watanabe et al. with regard to varying stoichiometry is that the proportion of one of the elements varies is one direction in the oxide through the depth of the stacked layers, thereby providing an apparent continual gradient from one elevation of the capacitor dielectric region to the other. (col.4, lns.27-39).

Yet, none of this is what Applicant recites in claim 1. Further, the reference in no way discloses or suggests what Applicant recites in claim 1. To arrive at the modification which the Examiner would make in finding claim 1 obvious requires hindsight reconstruction, which is impermissible. Alternately considered, to arrive at the conclusion of obviousness which the Examiner makes results in a fundamental modification of the reference teachings, with there being no such motivation for such modification in the reference. Applicant is not merely claiming varying stoichiometry in a high k capacitor dielectric region, but rather a specific relationship in the claim 1 combination. As this relationship is not shown nor suggested by Watanabe et al., independent claim 1 should be allowed, and action to that end is requested.

The independent claim 5 combination recites that one or more metals in the subject combination when bonded with oxygen has a first current leakage potential, and another of the metals when bonded with oxygen has a second current leakage potential which is greater than the first current leakage potential. The dielectric region layer comprises at least one portion having a greater concentration of the one metal bonded with oxygen which is more proximate at least one of the first and second electrodes <u>than another portion more proximate a center of the layer</u>. Watanabe et al. says absolutely nothing about one metal when bonded with oxygen as compared to another metal when bonded with oxygen having an effect on the magnitude of current leakage potential. Accordingly, it teaches nothing in this regard, and therefore, certainly does not teach or suggest anything other than positioning some portion having a greater concentration of any metal more proximate at least one of a first and second electrode than another portion more proximate a center of the layer.

Although Watanabe et al. does teach an apparent gradient in stoichiometry difference from one side of the region to another side in stepped stoichiometry differences between middle and outer regions in Table 1, it in no way discloses or suggests the specific relationship which Applicant recites in the independent claim 5 combination. <u>Again, such can only come from hindsight reconstruction, or reading a modification into the reference which the</u>

reference does not motivate. Accordingly, independent claim 5 should be allowed, and action to that end is requested.

The independent claim 12 combination should be allowed essentially for the same reasons argued above with respect to claim 5. In differing from claim 5, claim 12 talks about the absence of one metal in the oxide creating a vacancy, with the lack of vacancy in a second material of the layer having a second current leakage potential which is greater than the first leakage potential created by the vacancy. The claim 12 combination further recites that the high k capacitor dielectric region layer comprises at least one portion having a greater concentration of the first material which is more proximate at least one of the first and second electrodes than another portion more proximate a center of the layer. The arguments provided above regarding claim 5 equally apply to claim 12 with respect to the subject portions as affecting current leakage potential, here by creating a vacancy. Accordingly, independent claim 12 should be allowed, and action to that end is requested.

Applicant's independent claim 18 combination recites that the high k capacitor dielectric region includes a situation where one of the metals when bonded with oxygen has a first dielectric constant, and wherein another of the metals when bonded with oxygen has a second dielectric constant which is less than the first dielectric constant. The combination further includes that the layer comprises at least one portion having a greater concentration of the one metal bonded with oxygen more proximate a center of the layer than

another portion more proximate than <u>either of the first and second electrodes</u>. Under no stretch of the imagination could Watanabe et al. be concluded to render this claim obvious. Watanabe et al. only teaches, in one aspect, a continuous direction gradient from one electrode to another, and in the Table 1 embodiments, a center region which is the same in stoichiometry composition as at least one of the regions adjacent the electrode.

On the other hand, Applicant's claim 18 recites that the subject one portion has a greater concentration of the one metal bonded with oxygen which is more proximate a center of a layer than another portion more proximate <u>either</u> of the first and second electrodes. <u>Again, the only way an obviousness conclusion of Applicant's claim can be arrived at is by hindsight reconstruction, or by modifying the reference in a manner not motivated by it.</u> Accordingly, independent claim 18 should be allowed, and action to that end is requested.

Independent claim 25 should be allowed for essentially the same reasons argued above with respect to independent claim 18. Such also recites, in the combination, a layer comprising at least one portion having a greater concentration of a first material which is more proximate a center of a layer than another portion more proximate <u>either</u> of the first and second electrodes, where the first material and second material relationship is relative to an absence of one metal in the oxide creating a vacancy. For essentially

the same reasons as argued above with respect to claim 18, independent claim 25 should be allowed, and action to that end is requested.

Each of Applicant's dependent claims should be allowed as depending from allowable base claims, and for their own recited features which are neither shown nor suggested in the cited art.

This application is believed to be in immediate condition for allowance, and action to that end is requested. If the Examiner's next anticipated action is to be anything other than a Notice of Allowance, the undersigned respectfully requests a telephone interview prior to issuance of any such subsequent action.

Respectfully submitted,

Dated: 2-19-01

By: [signature]
Mark S. Matkin
Reg. No. 32,268

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Serial No. 09/388,063
Filing Date . . . . August 30, 1999
Inventor . . . . Vishnu K. Agarwal et al.
Assignee . . . . Micron Technology, Inc.
Group Art Unit 2815
Examiner . . . . J. Fenty
Attorney's Docket No. MI22-1196
Title: Capacitors Having a Capacitor Dielectric Layer Comprising a Metal Oxide Having Multiple Different Metals Bonded With Oxygen

MARKED-UP SPECIFICATION PARAGRAPHS ACCOMPANYING RESPONSE TO DECEMBER 20, 2000 OFFICE ACTION

To: Assistant Commissioner for Patents
Washington, D.C. 20231

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The replacement specification paragraphs incorporate the following amendments the last paragraph on page 6, beginning at line 15 and ending at page 7, line 2. Underlines indicate insertions and ~~strikeouts~~ indicate deletions.

A high k capacitor dielectric region 35 is positioned between first capacitor electrode 24 and second capacitor electrode 26. Capacitor dielectric region ~~34~~ 35 comprises a layer of metal oxide having multiple different metals bonded with oxygen, for example those materials described above. Most preferably and as shown, capacitor dielectric region 35 consists essentially of

such layer, meaning no other layers are received intermediate first electrode 24 and second electrode 26 which meaningfully impact the operation or capacitance of capacitor 32. In accordance with but one aspect of the invention, the metal oxide layer having multiple different metals bonded with oxygen has varying stoichiometry across its thickness. In other words, the stoichiometry in such layer is not substantially constant throughout the layer.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR LETTERS PATENT

* * * * *

Capacitors Having A Capacitor Dielectric Layer Comprising A Metal Oxide Having Multiple Different Metals Bonded With Oxygen

* * * * *

INVENTORS

Vishnu K. Agarwal
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ATTORNEY'S DOCKET NO. MI22-1196

Capacitors Having A Capacitor Dielectric Layer Comprising A Metal Oxide Having Multiple Different Metals Bonded With Oxygen

TECHNICAL FIELD

This invention relates to capacitors having a capacitor dielectric layer comprising a metal oxide having multiple different metals bonded with oxygen.

BACKGROUND OF THE INVENTION

As DRAMs increase in memory cell density, there is a continuing challenge to maintain sufficiently high storage capacitance despite decreasing cell area. Additionally, there is a continuing goal to further decrease cell area. One principal way of increasing cell capacitance is through cell structure techniques. Such techniques include three-dimensional cell capacitors, such as trenched or stacked capacitors. Yet as feature size continues to become smaller and smaller, development of improved materials for cell dielectrics as well as the cell structure are important. The feature size of 256Mb DRAMs and beyond will be on the order of 0.25 micron or less, and conventional dielectrics such as SiO_2 and Si_3N_4 might not be suitable because of small dielectric constants.

Highly integrated memory devices, such as 256 Mbit DRAMs, are expected to require a very thin dielectric film for the 3-dimensional capacitor of cylindrically stacked or trench structures. To meet this

requirement, the capacitor dielectric film thickness will be below 2.5nm of SiO_2 equivalent thickness.

Insulating inorganic metal oxide materials (such as ferroelectric materials, perovskite materials and pentoxides) are commonly referred to as "high k" materials due to their high dielectric constants, which make them attractive as dielectric materials in capacitors, for example for high density DRAMs and non-volatile memories. In the context of this document, "high k" means a material having a dielectric constant of at least 11. Such materials include tantalum pentoxide, barium strontium titanate, strontium titanate, barium titanate, lead zirconium titanate and strontium bismuth titanate. Using such materials enables the creation of much smaller and simpler capacitor structures for a given stored charge requirement, enabling the packing density dictated by future circuit design.

Certain high k dielectric materials have better current leakage characteristics in capacitors than other high k dielectric materials. In some materials, aspects of a high k material which might be modified or tailored to achieve a highest capacitor dielectric constant possible will unfortunately also tend to hurt the leakage characteristics (i.e., increase current leakage). For example, one class of high k capacitor dielectric materials includes metal oxides having multiple different metals bonded with oxygen, such as the barium strontium titanate, lead zirconium titanate, and strontium bismuth titanate referred to above. For example with respect to barium strontium titanate, it is found that increasing

titanium concentration as compared to barium and/or strontium results in improved leakage characteristics, but decreases the dielectric constant. Accordingly, capacitance can be increased by increasing the concentration of barium and/or strontium, but unfortunately at the expense of increasing leakage. Further, absence of titanium in the oxide lattice creates a metal vacancy in such multimetal titanates which can increase the dielectric constant, but unfortunately also increases the current leakage.

One method of decreasing leakage while maximizing capacitance is to increase the thickness of the dielectric region in the capacitor. Unfortunately, this is not always desirable. Another prior art method of decreasing leakage is described with respect to Fig. 1. There illustrated is a semiconductor wafer fragment 10 comprising a bulk monocrystalline silicon substrate 12. In the context of this document, the term "semiconductor substrate" or "semiconductive substrate" is defined to mean any construction comprising semiconductive material, including, but not limited to, bulk semiconductive materials such as a semiconductive wafer (either alone or in assemblies comprising other materials thereon), and semiconductive material layers (either alone or in assemblies comprising other materials). The term "substrate" refers to any supporting structure, including, but not limited to, the semiconductive substrates described above. A conductive diffusion region 14 is formed within substrate 12. An insulating dielectric layer 16 is formed over substrate 12, and includes an opening 18

formed therein to diffusion region 14. Opening 18 is filled with a suitable conductive material 20, for example conductively doped polysilicon or a metal such as tungsten. Barrier, silicide or other layers might also of course be utilized, but are not otherwise described.

A capacitor construction 22 is formed outwardly of insulating dielectric layer 16 and in electrical connection with conductive plugging material 20. Such comprises an inner capacitor electrode 24, an outer capacitor electrode 26, and a capacitor dielectric region 25 sandwiched therebetween. Capacitor dielectric region 25 comprises a composite of three layers 26, 27 and 28. Region 27 comprises a layer of metal oxide having multiple different metals bonded with oxygen, such as barium strontium titanate, fabricated to provide a stoichiometry which maximizes the dielectric constant of the material. As referred to above, this unfortunately adversely affects the desired leakage properties of the layer. Accordingly, layers 26 and 28 are received outwardly of layer 27 and comprise a material such as Si_3N_4 which exhibits extremely low current leakage. Unfortunately, Si_3N_4 has a considerably lower dielectric constant than the metal oxides having multiple different metals bonded with oxygen. Such adversely reduces the overall dielectric constant, and accordingly the capacitive effect of capacitor dielectric region 25.

SUMMARY

The invention comprises capacitors having a capacitor dielectric layer comprising a metal oxide having multiple different metals bonded with oxygen. In one embodiment, a capacitor includes first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween. The high k capacitor dielectric region includes a layer of metal oxide having multiple different metals bonded with oxygen. The layer has varying stoichiometry across its thickness. The layer includes an inner region, a middle region, and an outer region. The middle region has a different stoichiometry than both the inner and outer regions.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a diagrammatic view of a semiconductor wafer fragment processed in accordance with the prior art, as discussed in the "Background" section above.

Fig. 2 is a diagrammatic sectional view of a semiconductor wafer fragment in accordance with the invention.

Fig. 3 is a diagrammatic view of a chemical vapor deposition chamber utilized in accordance with an aspect of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

The invention is described in one exemplary structural embodiment as depicted by Fig. 2. Like numerals from the Fig. 1 prior art embodiment are utilized where appropriate, with differences being indicated with different numerals. Fig. 2 depicts a wafer fragment 30 comprising a capacitor 32 having first and second electrodes 24 and 26. Example and preferred materials for electrodes 24 and 26 include conductively doped polysilicon, conductively doped hemispherical grain polysilicon, platinum, ruthenium, ruthenium oxides, iridium, iridium oxides, palladium, tungsten, tungsten nitride, tantalum nitride, titanium nitride, titanium oxygen nitride, and the like.

A high k ~~capacitor~~ dielectric region 35 is positioned between first capacitor electrode 24 and second capacitor electrode 26. Capacitor dielectric region ~~34~~ 35 comprises a layer of metal oxide having multiple different metals bonded with oxygen, for example those materials described above. Most preferably and as shown, capacitor dielectric region 35 consists essentially of such layer, meaning no other layers are received intermediate first electrode 24 and second electrode 26 which meaningfully impact the operation or capacitance of capacitor 32. In accordance with but one aspect of the invention, the metal oxide layer having multiple different metals bonded with oxygen has varying

stoichiometry across its thickness. In other words, the stoichiometry in such layer is not substantially constant throughout the layer.

In accordance with but one aspect of the invention, consider a high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen. One of the metals when bonded with oxygen has a first current leakage potential, while another of the metals when bonded with oxygen has a second current leakage potential which is greater than the first current leakage potential. By way of example only, consider a titanate, such as barium strontium titanate. Titanium is an example of one metal which when bonded with oxygen has a lower current leakage potential than either barium or strontium when bonded with oxygen. In this embodiment, the layer comprises at least one portion having a greater concentration of the one metal bonded with oxygen which is more proximate at least one of the first and second electrodes than another portion which is more proximate a center of the layer.

By way of example only, capacitor 32 depicts capacitor dielectric region and layer 35 as comprising an inner region 36, a middle region 38, and an outer region 40. Regions 36 and 40 most preferably constitute portions which are fabricated to have a greater concentration of the one metal, in this example titanium, bonded with oxygen than portion 38. Accordingly, regions 40 and 36 are more proximate at least one of the first and second electrodes than is portion 38 more proximate a center of the layer within capacitor dielectric region 35.

Accordingly, the layer or region 35 in this example comprises portions 36 and 40 having a greater concentration of the one metal bonded with oxygen more proximate both the first and second electrodes than the another portion 38 more proximate the center of the layer of capacitor dielectric region 35. Further preferably, region 38 has a greater concentration of the another of the metals (i.e., a greater concentration of one or both of barium and strontium) bonded with oxygen than portions 36 and 40. Further in this preferred example, at least one of portions 36 and 40 (both of such portions as shown) contacts one of the first and second electrodes. As shown, portion 36 contacts electrode 24, while portion 40 contacts electrode 26. Regions 36, 38 and 40 can be fabricated to be the same thickness or different relative thicknesses. Further by way of example only, regions 36 and 40 can be fabricated to comprise essentially the same stoichiometry or different stoichiometries. Accordingly, Fig. 2 depicts but one example where the high k capacitor dielectric region includes a layer where a middle region has a different stoichiometry than both inner and outer regions.

In an additional or alternate aspect or consideration, consider a high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, where one of the metals when bonded with oxygen produces a first material having a first current leakage potential. Further, absence of the one metal in the oxide creates a vacancy and a second material having a second current

leakage potential which is greater than the first current leakage potential. An example would be a multiple metal component titanate, such as barium strontium titanate, where the one metal comprises titanium. In accordance with this implementation, the metal oxide layer comprises at least one portion having a greater concentration of the first material which is more proximate at least one of the first and second electrodes than another portion which is more proximate a center of the layer.

Again, Fig. 2 illustrates an exemplary construction, whereby at least one of portions 36 and 40 can be fabricated to have a greater concentration of the first material than another portion 38. Again using barium strontium titanate as an example, titanium constitutes a metal in such material which, when bonded with oxygen, produces greater current leakage potential or resistance than when a vacancy is created in the oxide by absence of the titanium atoms. Accordingly, barium and strontium quantity could essentially be constant throughout the layer of capacitor dielectric region 35, with only the quantity of titanium varying relative to such regions such a described in the preferred example immediately above.

In an additional or alternate considered aspect of the invention, consider a high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, where one of the metals when bonded with oxygen has a first dielectric constant. Another of the metals of such layer when bonded with oxygen has a

second dielectric constant which is less than the first dielectric constant. The layer comprises at least one portion having a greater concentration of the one metal bonded with oxygen more proximate a center of the layer than another portion more proximate either of the first and second electrodes. By way of example only, barium strontium titanate constitutes one such material. Specifically, barium and strontium in such material constitutes metals which, when bonded with oxygen, produce a first dielectric constant which is greater than when titanium is bonded with oxygen. Accordingly, and again by way of example only and in reference to the above Fig. 2, region 38 constitutes the one portion having a greater concentration of the one metal (i.e., one or both of barium and strontium) bonded with oxygen which is more proximate a center of the layer.

In an additional or alternate considered aspect of the invention, consider a high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, where one of the metals when bonded with oxygen produces a first material having a first dielectric constant. Absence of the one metal in the oxide creates a vacancy, and a second material having a second dielectric constant which is less than the first dielectric constant. The metal oxide layer comprises at least one portion having a greater concentration of the first material which is more proximate a center of the layer than another portion which is more proximate either of the first and second electrodes.

Again using barium strontium titanate as an example, barium and strontium are example metals whose absence in the lattice when producing vacancies results in a dielectric constant which is less than when present. Accordingly in this example with respect to barium strontium titanate, the one metal comprises at least one of barium and strontium. An exemplary construction encompassing the same is again as depicted in Fig. 2.

The above-described preferred embodiment was with respect to multiple component titanates wherein both the current leakage potential and dielectric constant aspects of the invention are met in the same material. Alternate materials are also, of course, contemplated whereby perhaps only one of the current leakage potential relationship or the capacitor dielectric constant relationship results, with the invention only being limited by the accompanying claims appropriately interpreted in accordance with the Doctrine of Equivalents.

Fig. 3 depicts an exemplary process of depositing a dielectric layer comprising metal oxide having multiple different metals bonded with oxygen in accordance with an aspect of the invention. A chemical vapor deposition chamber 70 has a substrate 72 upon which deposition is desired positioned therein. Exemplary multiple gas inlets 76, 77, 78 and 80 are depicted schematically as extending to chamber 70. Fewer or more gas inlets could, of course, be provided. Further, gases could be mixed further upstream of the schematic depicted by Fig. 3, and flowed as mixtures or combinations relative to one or more inlets.

Multiple gaseous precursors are fed to the chamber under conditions effective to deposit the dielectric layer having multiple different metals bonded with oxygen on substrate 72. At least some of the precursors comprise different metals of the respective multiple different metals bonded with oxygen, which is deposited in the layer on the substrate. As one example, a process for depositing (Ba,Sr) TiO_3 includes utilizing precursors of $Ba(DPM)_2$, $Sr(DPM)_2$ and $Ti(OC_3H_7)_4$, O_2 at 0.5 Torr and 410°C, where "DPM" denotes "dipivaloylmethanato". For example, one of each of these gases could be flowed from the respective inlets 76, 77, 78 and 80. In accordance with one implementation, the flow of at least one of the precursors is varied during the feeding to achieve different concentrations of the different metals bonded with oxygen at different depths in the deposited layer.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

CLAIMS:

1. A capacitor comprising first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween, the high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, the layer having varying stoichiometry across its thickness, the layer comprising an inner region, a middle region, and an outer region, the middle region having a different stoichiometry than both the inner and outer regions.

2. The capacitor of claim 1 wherein the inner and outer regions have essentially the same stoichiometry.

3. The capacitor of claim 1 wherein the metal oxide with multiple different metals bonded with oxygen comprises a ferroelectric material.

4. The capacitor of claim 1 the capacitor dielectric region consists essentially of the layer.

5. A capacitor comprising first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween, the high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, one of the metals when bonded with oxygen having a first current leakage potential, another of the metals when bonded with oxygen having a second current leakage potential which is greater than the first current leakage potential, the layer comprising at least one portion having a greater concentration of the one metal bonded with oxygen which is more proximate at least one of the first and second electrodes than another portion more proximate a center of the layer.

6. The capacitor of claim 5 wherein the another portion has a greater concentration of the another of the metals bonded with oxygen than the one portion.

7. The capacitor of claim 5 wherein the layer comprises portions having a greater concentration of the one metal bonded with oxygen more proximate both the first and second electrodes than the another portion more proximate the center of the layer.

8. The capacitor of claim 5 wherein the at least one portion contacts the one electrode.

9. The capacitor of claim 5 wherein the layer comprises portions having a greater concentration of the one metal bonded with oxygen more proximate both the first and second electrodes than the another portion more proximate the center of the layer, said greater concentration portions respectively contacting the first and second electrodes.

10. The capacitor of claim 5 wherein the metal oxide with multiple different metals bonded with oxygen comprises a titanate, and the one metal comprises titanium.

11. The capacitor of claim 5 the capacitor dielectric region consists essentially of the layer.

12. A capacitor comprising first and second conductive electrodes having a high-k capacitor dielectric region positioned therebetween, the high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, one of the metals when bonded with oxygen producing a first material having a first current leakage potential, absence of the one metal in the oxide creating a vacancy and a second material having a second current leakage potential which is greater than the first current leakage potential, the layer comprising at least one portion having a greater concentration of the first material which is more proximate at least one of the first and second electrodes than another portion more proximate a center of the layer.

13. The capacitor of claim 12 wherein the layer comprises portions having a greater concentration of the first material more proximate both the first and second electrodes than the another portion more proximate a center of the layer.

14. The capacitor of claim 12 wherein the at least one portion contacts the one electrode.

15. The capacitor of claim 12 wherein the layer comprises portions having a greater concentration of the first material more proximate both the first and second electrodes than the another portion more proximate a center of the layer, said greater concentration portions respectively contacting the first and second electrodes.

16. The capacitor of claim 12 wherein the metal oxide with multiple different metals bonded with oxygen comprises a titanate, and the one metal comprises titanium.

17. The capacitor of claim 12 the capacitor dielectric region consists essentially of the layer.

18. A capacitor comprising first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween, the high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, one of the metals when bonded with oxygen having a first dielectric constant, another of the metals when bonded with oxygen having a second dielectric constant which is less than the first dielectric constant, the layer comprising at least one portion having a greater concentration of the one metal bonded with oxygen more proximate a center of the layer than another portion more proximate either of the first and second electrodes.

19. The capacitor of claim 18 wherein the another portion contacts one of the first and second electrodes.

20. The capacitor of claim 18 wherein the another portion has a greater concentration of the another of the metals bonded with oxygen than the one portion.

21. The capacitor of claim 18 wherein the layer comprises portions having a greater concentration of the another metal bonded with oxygen more proximate both the first and second electrodes than the one portion more proximate the center of the layer, said greater concentration portions respectively contacting the first and second electrodes.

22. The capacitor of claim 18 the capacitor dielectric region consists essentially of the layer.

23. The capacitor of claim 18 wherein the metal oxide with multiple different metals bonded with oxygen comprises a titanate, and the another metal comprises titanium.

24. The capacitor of claim 18 wherein the metal oxide with multiple different metals bonded with oxygen comprises barium strontium titanate, and the one metal comprises at least one of barium and strontium.

25. A capacitor comprising first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween, the high k capacitor dielectric region comprising a layer of metal oxide having multiple different metals bonded with oxygen, one of the metals when bonded with oxygen producing a first material having a first dielectric constant, absence of the one metal in the oxide creating a vacancy and a second material having a second dielectric constant which is less than the first dielectric constant, the layer comprising at least one portion having a greater concentration of the first material which is more proximate a center of the layer than another portion more proximate either of the first and second electrodes.

26. The capacitor of claim 25 wherein the layer comprises portions having a greater concentration of the first material more proximate both the first and second electrodes than the another portion more proximate a center of the layer.

27. The capacitor of claim 25 wherein the another portion contacts the one electrode.

28. The capacitor of claim 25 wherein the layer comprises portions having a greater concentration of the another material more proximate both the first and second electrodes than the one portion more proximate a center of the layer, said greater concentration portions respectively contacting the first and second electrodes.

29. The capacitor of claim 25 the capacitor dielectric region consists essentially of the layer.

30. The capacitor of claim 25 wherein the metal oxide with multiple different metals bonded with oxygen comprises a titanate.

31. The capacitor of claim 25 wherein the metal oxide with multiple different metals bonded with oxygen comprises barium strontium titanate, and the one metal comprises at least one of barium and strontium.

ABSTRACT OF THE DISCLOSURE

The invention comprises capacitors having a capacitor dielectric layer comprising a metal oxide having multiple different metals bonded with oxygen. In one embodiment, a capacitor includes first and second conductive electrodes having a high k capacitor dielectric region positioned therebetween. The high k capacitor dielectric region includes a layer of metal oxide having multiple different metals bonded with oxygen. The layer has varying stoichiometry across its thickness. The layer includes an inner region, a middle region, and an outer region. The middle region has a different stoichiometry than both the inner and outer regions.

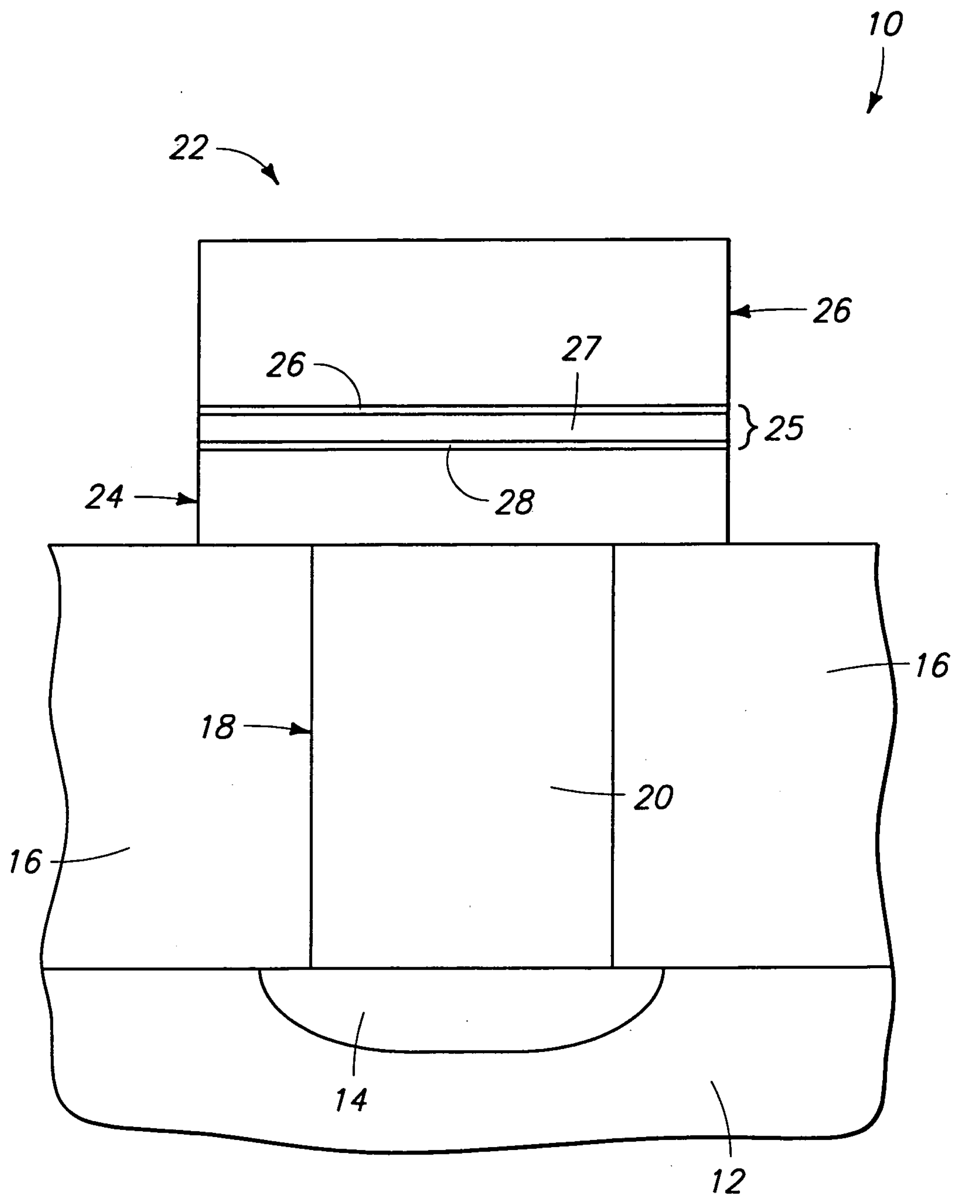

Fig 1
PRIOR ART

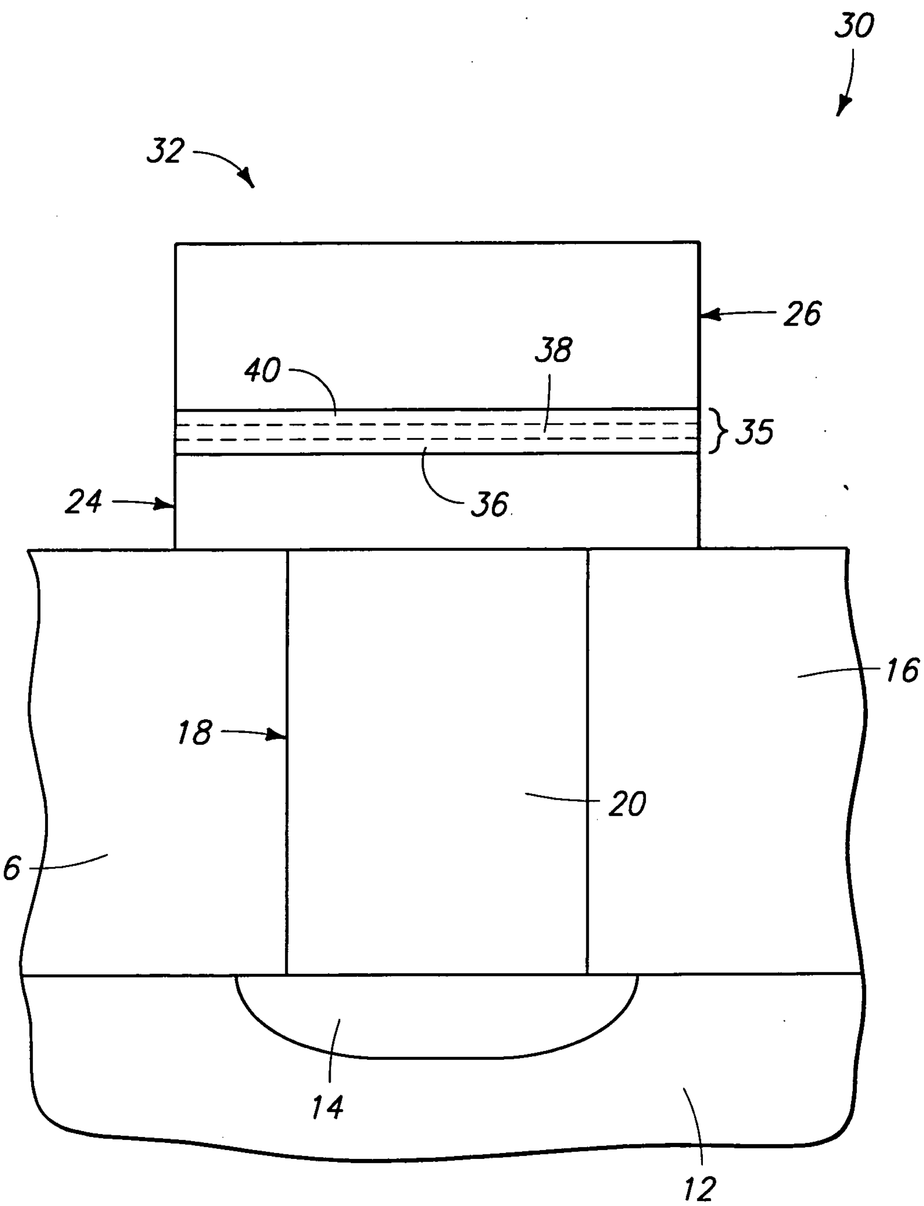

Fig 2

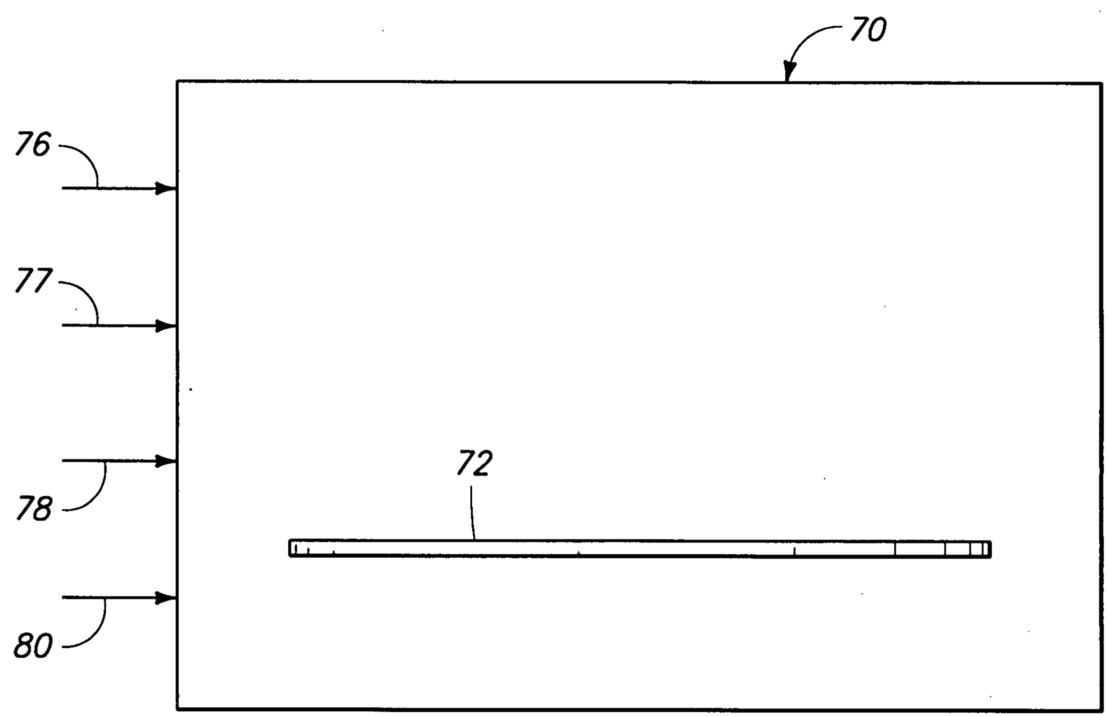

FIG. 3